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## **Polycystic ovary syndrome (PCOS) and alteration of vocal function: a systematic review and meta-analysis**

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# Polycystic ovary syndrome (PCOS) and alteration of vocal function: a systematic review and meta-analysis

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Running title: PCOS and alteration of vocal function

## Abstract

**Introduction:** Polycystic ovary syndrome (PCOS) is a common hormonal disorder among young women, correlated with hyperandrogenism. Among the symptoms of PCOS, vocal alterations are quite unknown. Dysphonia may be related to hyperandrogenism, and there is no consensus about its prevalence and the severity of vocal disorders, which can cause noticeable discomfort.

**Methods:** A systematic review of the literature was conducted. Four studies on PCOS that evaluated the phonatory system were included, for a total of 174 patients (96 PCOS, 78 controls) and a meta-analysis on comparable data was performed.

**Results:** Four studies evaluated parameters related to vocal symptomatology, altered audiometric examination, and findings at the laryngoscopy in patients affected by PCOS versus controls. Although the individual studies showed increased incidence of alterations and a tendency to speech fatigue in women with PCOS, when the

results of studies were pulled in metanalysis the overall difference was not statistically significant. The studies themselves were very different from each other, thereby it is hard to draw any firm conclusions.

**Discussion/Conclusions:** The aim of this study was to assess the prevalence of vocal alterations, the correlation with hyperandrogenism, the quality of life, and the voice changes after starting a therapy for PCOS. The present meta-analysis failed to find any difference in terms of PCOS and control cohort. However, the lack of high-quality studies makes it difficult to draw firm conclusions. New and larger studies or big population program data are therefore warranted.

**Keywords:** PCOS, dysphonia, voice change, polycystic ovarian syndrome, hyperandrogenism.

## Introduction

Polycystic ovary syndrome (PCOS) is a common hormonal disorder that affects women of reproductive age. PCOS is characterized by a combination of symptoms that can include irregular menstrual periods, excess of androgen levels, and the formation of small ovarian cysts. The exact cause of PCOS is not fully elucidated, although a combination of genetic and environmental factors may play a role [1,2]. Symptoms of PCOS can include acne, weight gain and infertility due oligo-anovulation. This syndrome is also associated with an increased risk of developing certain health conditions, such as diabetes and heart disease. PCOS is diagnosed through a combination of symptoms, physical exam, and lab tests. Hyperandrogenism, which is a common feature of PCOS, refers to an excess of androgen hormones that can cause a variety of symptoms, including hirsutism, acne, and alopecia [1,2]. Voice change, also known as dysphonia, is a less common symptom of hyperandrogenism, but it has been reported in some women with PCOS [3,4,5,6]. In fact, the androgens have an effect on the larynx, causing the thickening of the vocal cords and resulting in alterations of the voice. Therefore, the voice change could be considered as a possible symptom of PCOS, especially when correlated with other symptoms. The purpose of this systematic review is to evaluate the potential correlation between voice change and PCOS. Existing studies on the topic will be examined to determine if voice changes are a common symptom of PCOS and if the treatment of PCOS could have an effect on voice changes.

## Methods

### 2.1 Information Sources

A systematic literature search was performed in the databases of PubMed, Cochrane, and Web of Science until January 2023, without using date limit or language restrictions. The study protocol was registered online on PROSPERO. The review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [7]. The search has been limited to studies published in peer-reviewed journals.

### 2.2 Search Strategy

The search items or keywords used were "polycystic ovary syndrome" (Medical Subject Headings – MeSH Unique ID: D011085), "PCOS", "voice change", "dysphonia" (MeSH Unique ID: D055154) and "hyperandrogenism" (MeSH Unique ID: D017588). A manual screening of reference lists of identified studies and reviews was performed to identify any other eligible studies. No contact with Authors was necessary. All searchers involved in the development of the present paper were physicians.

### 2.3 Study selection

Two independent reviewers had screened the titles and abstracts of the studies identified in the search to determine their eligibility for inclusion in the review based on pre-defined criteria. The articles included were observational studies that compared patients affected by PCOS with a similar healthy, control group and that described symptoms, results of the acoustical analysis or instrumental findings. All studies that do not meet these criteria were excluded. To reach a high methodological quality, case reports, editorials, and reviews were also excluded. Any discrepancies have been resolved through discussion and consensus.

### 2.4 Data extraction

Relevant data from the studies have been extracted and organized using a predefined data extraction form, in order to ensure consistency. For each eligible article, the authors collected the study design, the sample size of patients, the median age, the aim of the study, the tools used, the subjective and objective findings about dysphonia, the results from instrumental investigation, and finally main findings and conclusions of the study. Mean values and p-values were reported. Any discrepancies were identified and resolved through discussion (with a third external collaborator where necessary).

### 2.5 Quality assessment

The quality of the studies has been assessed by two Authors who worked independently using the Cochrane Risk of Bias tool. The risk of bias of studies included in the meta-analysis was assessed according to The Risk of Bias In Non-randomized Studies of Interventions (ROBINS-I) [8]. Details in **Supplementary materials – Figure S1**.

## 2.6 Data synthesis

The data from the studies have been synthesized and analyzed using a narrative synthesis approach to identify patterns and trends. Pooled results were expressed as standard mean difference (SMD) with 95% Confidence Interval (CI). P value lower than 0.05 was considered as statistically significant. Higgins  $I^2$  was used to assess heterogeneity (defined as high when  $I^2$  was  $\geq 50\%$  and low when  $I^2$  was  $< 50\%$ ). Less than ten studies were included in pooled analysis, so testing for funnel plot asymmetry was not possible for the assessment of publication bias.

## 2.7 Outcomes

The following outcomes were evaluated:

- 1) Patient-Reported Outcomes (PROs): patient's perceived voice quality evaluated by questionnaires about the subjective impact that a vocal problem produces in the subject.
- 2) Severity of voice change: degree of dysphonia in women with PCOS.
  - 2.1 Degree of dysphonia evaluated with acoustic analysis obtained from voice recording in order to digitize, analyze and quantify the vocal changes.
  - 2.2 Anatomic-functional analysis performed with laryngoscopy.
- 3) Correlation between dysphonia and androgens' level: the relationship between androgens and the presence or severity of voice change in women with PCOS.
- 4) Impact on quality of life (QoL): the effect of voice change on the quality of life of women with PCOS, including the effect on their work and personal life.
- 5) Effect of PCOS treatment on voice change: the effect of different treatment options for PCOS on dysphonia in women with PCOS.

## Results

### 3.1 Literature Search

All searchers were physicians. A total of 42 records were identified and, according to the PRISMA system, considered as it follows. After the elimination of 13 duplicates, 29 records were manually screened. Based on the abstract, 15 papers were further excluded. The full-text articles assessed for eligibility were 14, and after the removal of 7 records due to publication type and 3 records not published in English, 4 studies were included in the systematic review. Details about the literature search results are reported in **Figure 1**.

### 3.2 Study characteristics and patients' characteristics

Overall, 174 patients were included in this systematic review: 78 were healthy patients enrolled as controls and 96 had a diagnosis of PCOS according to Rotterdam Criteria (presence of two of three of the following criteria: oligo-anovulation, hyperandrogenism and polycystic ovaries on ultrasound) [9]. The number of patients ranged between 17 and 30 for the PCOS group. The age of patients ranged between 18 and 39 years. A total of 4 prospective, monocentric studies were included [3,4,5,6].

The main characteristics of the studies, including patient's inclusion and exclusion criteria, endpoint/outcomes evaluated and tools used for the research can be found in **Supplementary materials – Table S1**.

### 3.3 Patient-Reported Outcomes (PROs):

Data on perceived voice quality was assessed by standardized and non-standardized scales was reported in 4 studies. [3,4,5,6] Unfortunately, due to the different parameters and questionnaires tested in the studies considered for this review, the data were not comparable in order to perform a meta-analysis. Results are shown in **Supplementary materials – Table S2**.

#### 3.3.1: Voice Handicap Index (VHI)

Information about perceived voice quality was assessed by standardized scales as the Voice Handicap Index 10 (VHI-10) in one study [4] and VHI is a 30-item scale used in one different study [3]. The VHI is a 30-item instrument designed to examine the self-perceived emotional, physical, and functional effects of patients' voice dysfunction [10,11]. Gugatschka et al. [3] reported in 34 patients no statistically significant difference in term of mean VHI-30 German Version total score ( $p=0.6$ ), that was  $8.1 (\pm 9.5)$  in PCOS patients and  $10.1 (\pm 11.5)$  in the control group, respectively, or in subscales. However, this study does not report the incidence of patients with a pathological score (cutoff  $> 11$ ). The VHI-10 is a valid instrument, with a slight loss of information respect to the VHI-30, to quantify the patients' own perception of voice [10,11]. According to Aydin et al. [4], pathologic scores in VHI-10 were found, on a total of 52 women, in 6.7% (2/30) of patients affected by PCOS compared with 0% (0/22) of controls. This difference was not statistically significant ( $p=0.387$ ).

### 3.3.2: Glottal Function Index (GFI)

One study evaluated the Glottal Function Index (GFI) [4]. The GFI is a 4-item symptom index to assess the four main symptoms of glottal incompetence: effortful talking, vocal pain after talking, vocal fatigue, and voice cracks [4]. Aydin et al. [4] performed the evaluation of GFI in 52 patients that showed a statistically significant glottal incompetence in 23.3% (7/30) of PCOS patients and 4.5% (1/22) of controls ( $p=0.048$ ).

### 3.3.3 Reflux Symptom Index (RSI)

One study evaluated the Reflux Symptom Index (RSI) [4]. The RSI is a 9-item instrument for evaluating symptoms of laryngopharyngeal reflux. Each item is scored between 0 (no problem) and 5 (severe problem), with a maximum total score of 45. An RSI of greater than 13 is considered to indicate laryngopharyngeal reflux [4]. The RSI was found, on 52 total women, elevated in 6.7% (2/30) of patients affected by PCOS and in 4.5% of the controls (1/22).

### 3.3.4 Non standardized questionnaires

Only one study tested the PROs by personalized and no standardized questionnaires on 38 women [5]. Hannoun et colleagues [5] investigated, by personalized and no standardized questionnaires, the presence of the following vocal symptoms: throat clearing, deepening of the voice, loss of voice, lump in the throat, and difficulty being heard. They found that patients with PCOS had a significantly higher prevalence of symptoms compared to controls. A throat clearing was present in 75.6% (13/19) of PCOS patients and 4.8% (1/21) of the control group ( $p=0.0001$ ) and a deepening of the voice in 35.3% (6/17) of women with PCOS compared with 9.5% of controls ( $p=0.05$ ). The presence of a lump in throat was perceived in 41.2% (8/19) of PCOS patients and difficulty being heard was reported in 17.6% (3/17) of them, compared respectively to 9.5% (2/21) and 0% of controls ( $p=0.02$  and  $p=0.045$ ). Loss of voice wasn't different (47.6% of PCOS, 23.5% of controls,  $p=0.126$ ).

## 3.4 Severity of voice change

### 3.4.1 Degree of dysphonia evaluated with acoustic analysis

The dysphonia was objectively evaluated with the acoustic analysis of a voice record in 3 out of 4 studies [3,4,5] for a total of 124 patients (71 PCOS and 53 controls). In all 3 researches [3,4,5] the main vocal parameters analyzed were: Fundamental Frequency (F0): the rate of vibration of the glottis which oscillate in the airflow when appropriately tensed; Noise-to-Harmonic Ratio (NHR): the ratio between the total energy of the periodic voice signal and the energy of noise components; Shimmer: the relative variability in the amplitude of sound waves) [12]. Two out of 4 studies [3,5] evaluated the values of Maximum Phonation Time (MPT), or longest period during which a patient can sustain phonation of a vowel sound, typically “//a”. Two out of 4 studies [3,4] evaluated the Jitter, or the variability in the F0 between contiguous glottal cycles.

#### 3.4.1.1 Fundamental Frequency (F0)

Three of the studies included the F0 representing a cohort of 124 participants (71 in the PCOS group and 53 in the control group) [3,4,5]. The standard mean difference (SMD) was -0.25 (95% CI -0.64 to 0.14),  $p < 0.21$ . Details in **Figure 2**.

#### 3.4.1.2 Noise-to-Harmonic Ratio (NHR)

Three of the studies included NHR calculated on 124 patients [3,4,5]. Notably, the study of Aydin et al. [4] are reported the values of NHR in PCOS group of  $22.0 \pm 4.7$  and  $21.7 \pm 4.3$  in controls group. The NHR measures the ratio between periodic and non-periodic components of a speech sound. However, this values probably is referred to the Harmonics to noise ratio (HNR) that express the ratio between non-periodic and periodic components of the sounds. For that reason, the comparative analysis has been performed on only two studies [3,5]. The SMD was 0.19 [95% CI -0.30, 0.67],  $p=0.45$ . Details in **Figure 3**.

#### 3.4.1.3 Shimmer

Three of the study included the Shimmer representing a cohort of 124 participants (71 in the PCOS group and 53 in the control group) [3,4,5]. The standard mean difference was 0.02 [-0.35, 0.38], with a 95% CI,  $p=0.93$ . Details in **Figure 4**.

#### 3.4.1.4 MPT

MPT was compared in 47 patients with PCOS and 43 controls [3,5]. The SMD was -0.34 [95% IC -1.94, 1.25],  $p=0.67$ . Details in **Supplementary materials – Figure S2**.

#### 3.4.1.5 Jitter

The Jitter parameter was evaluated in 2 of the 4 studies considered in the review [3,4], on 54 PCOS cases and 32 controls. SMD calculated was -0.12 [95% CI, -0.57, 0.32],  $p=0.58$ . Details in **Supplementary materials – Figure S3**

#### 3.4.1.6 Other analysis

Other analysis was evaluated in singles study and a comparative analysis was not possible to perform: No difference in terms of Voice Turbulence Index (VTI) [5], Soft Phonation Index (SPI) [5], lowest pitch and higher pitch [3], minimum frequency and maximum frequency [4] was reported. In one study an increase in the “Relative average perturbation” (RAP) in PCOS patients was reported [5]. Detailed data are reported in **Supplementary Materials - Table S2**.

#### *3.4.2 Anatomic-functional analysis performed with laryngoscopy*

In 3 out of 4 studies [4,5,6] direct viewing of the larynx with fiberoptic laryngoscope or videostroboscopy was performed, and allowed to identify any organic or functional alterations of the phonatory system. Unfortunately, data were not comparable because of the parameters analyzed were different depending on the research group. The following parameters were statistically different in patients with PCOS compared with healthy women increased supraglottic hyperfunction [4]; increased incomplete glottis closure [4]; increased mediolateral compression [4]; reduced amplitude of vibration [4]; increased abnormal mucosal wave [4]; increased surrounding structural interference [6]; increased cycle-to-cycle variability [6]; increased rounded shape of lateral peaks [6]; All the instrumental findings are summarized in **Supplementary materials - Table S3**.

#### *3.5 Correlation between dysphonia and androgens' level*

None study evaluated the correlation between blood androgens' level and vocal changes. However, two studies [3,4] performed blood tests to assess the difference in sex hormones between the PCOS group and the control group, finding significantly higher levels of androgens (testosterone, androstenedione, DHEAS) in patients with polycystic ovarian syndrome. The findings are summarized in **Supplementary materials - Table S2**.

#### *3.6 Impact on QoL*

The impact of dysphonia on QoL has not been openly investigated in any of the reviewed studies. Anyway, QoL can be evaluated through the scores of the VHI scales. Of the two studies that used the Voice Handicap Index, one [4] reported not only the total score but also the psychological (p) and emotional (e) subscales. There is no statistically significant difference between the group affected by PCOS and the controls in the p-VHI (p=0.6) and e-VHI (p=0.9) subscales.

#### *3.7 Effect of PCOS treatment on voice change*

To our knowledge, none of these studies investigated the effect of different treatment available for PCOS on the dysphonia.

### **Discussion**

#### *Main Findings*

The present meta-analysis found no significant differences between women with PCOS and the control group in terms of F0, noise to harmonic ratio, shimmer, maximum phonation time, and jitter value. The review also did not uncover any comparable symptoms or laryngoscopy results. Moreover, the quality of life was evaluated through the Voice Handicap Index but was not comparable to other values. There were no reports on the effects of treatment on dysphonia.

#### *Strengths and Limitations*

The strength of this review relies on its systematic approach according to PRISMA recommendations. A major drawback of the available data is the use of various methods and scales to assess both subjective and objective aspects, making it difficult to compare results across studies. Additionally, many studies have a limited sample size. Furthermore, the absence of standardized selection's criteria based on androgen levels among patients with PCOS may result in a heterogeneous population and may obscure any potential association between androgens and laryngeal modifications. For this reason, in further studies it would be useful to focus on the specific population of PCOS patients with hyperandrogenism, in order to understand their action on vocal parameter. A cutoff level of androgens that leads to changes in the components of the speech production system should be assessed. Having these parameters defined could serve as a predictor of discomfort and complications, allowing early intervention and prevention efforts.

#### *Interpretation*

The voice is considered a secondary sexual character and organ [13,14]. Several studies demonstrated that the hormones affect the vocal production [13, 15,16,17,18] and that androgenous receptors in laryngeal cells are present [19-21]. During puberty, the enlargement and lengthening of the larynx leads to an aggravation of F0 of about one octave in the male and 3-4 semitones in the female [13]. The impact of sexual development on the voice is illustrated by the retention of feminine voice characteristics in those boys who underwent orchiectomy before puberty [14]. In the XVII and XVIII centuries, the brutal practice of eversion made the “Castrati” capable of performing very demanding and impressive vocal parts, which made them irreplaceable elements for

performances [22]. A premenstrual vocal syndrome characterized by lowered vocal intensity, vocal fatigue, a decreased range with loss of the high tones and a loss of vocal quality has been described [23-25]. Recently, Abitbol and colleagues [26] evaluated the laryngeal vascular characteristics which changes were evident throughout the menstrual cycle, suggesting increased congestion during premenstrual days correlated to variations in progesterone and especially evident at its premenstrual peak. In menopause, estrogen deficiency affects the dryness and thinning of the mucous membranes, and women also complain about the lower tonality of voice and the worsening of hoarseness [15]. The fall of estrogen levels and the relative increase of androgen levels affects the laryngeal structures with thickening and edema of the vocal folds, prominence of the vocal process and increased glottal contact during phonation. The results are the reduction of the breathiness, lowered F0 with deeper tone of voice and vocal virilization [27]. On the contrary, in aged men the chordal thinning due to muscular hypotrophy, the reduction of the phonatory contact and the increase of the fundamental frequency are physiologically observed and have been related to androgens decrease ("feminization" of the timbre) [28]. Hypogonadism has also been studied, with concern about testosterone replacement, reporting significant vocal register and voice quality changes in singers [29,30]. Among the different androgens testosterone is the most studied hormone that affect the voice. In literature is described how after the hormone replacement therapy (HRT) with exogenous testosterone the primary effect on speech is the decrease of the Fundamental Frequency [31] and **in fourth formant frequencies** [32]. About other androgens in literature there are few studies. Also there is evidence that, when androgenic-agents are used in females (danazol, nandrolene decanoate, testosterone, oxandrolone), some symptoms can present as hoarseness in vocal quality, lowering of habitual pitch, difficulty projecting speaking voices, and loss of control over their singing voices [33,34]. In literature are still debated the long-term effects of high androgen's levels on voice changes. In the study performed by Chadwick and colleagues, female patients treated with androgen supplementation experienced some benefits after the cessation of hormone therapy, as the reduction of Fundamental Frequency and the improvement of VHI-10 values. Unfortunately, voice changes may be permanent and the role of voice therapy is unclear [35]. Baker et al reported on a small sample of women that, after withdrawal of the drugs and 6 months of voice therapy, some symptoms remained permanent, suggesting significant alteration in vocal physiology (as muscular coordination dysfunction, muscle tissue changing, and proprioceptive dysfunction) [34]. Currently, there are conflicting results regarding the influence of a moderate androgenic alteration in patients with PCOS on objective and subjective vocal parameters [3,4,5,6]. Looking at the individual studies included, there are some findings that need to be clarified. Considerable difference about symptoms between the two cohorts (increased throat clearing, deepening of voice, difficulty being heard, lump in throat) has been reported by Hannoun et al. [5]. Unfortunately, without a complete hormonal assessment (testosterone level was tested only for eleven of enrolled patients) it is difficult to evaluate a possible correlation. In the analysis of all the acoustic data, the increase in RAP, reflecting a perturbation of the voice, and the decrease in MPT in patients with PCOS [5] were overall the only differences identified. Gugatschka and co-workers [3] reported even a mild trend toward lower mean F0 (Hz) in their study cohort (201 vs 210 Hz), but not statistically significant. Interestingly, these similar symptoms and acoustic parameters were recorded despite a significant difference of serum androgens level [3,4], suggesting that this androgenous level was maybe is not so high to determine a laryngeal alteration sufficient to reflect on symptoms and on voice's production. On regards of instrumental findings, an abnormal muscle tension patterns, an impaired vocal fold vibration and a supraglottic hyperfunction were observed based on stroboscopic findings in women with PCOS, in a group that had a mean value of testosterone of  $61.3 \pm 26.7$  ng/dL (higher than healthy women, with a mean value of  $35.5 \pm 12.2$  ng/dL) [4]. The recent study performed by Blahayil et al. [6] used a videokymographic (VKG) camera and a laryngoscope in order to produce a video record and vocal folds scans of the vibration of the glottal length. Of interest, VKG's high quality of image can show vocal fold vibratory motions otherwise impossible to detect [6]. Noteworthy, this study revealed many differences between the PCOS population and the healthy controls, suggesting a possible underestimation of vocal alterations achieved with other methods. Unfortunately, in that manuscript the symptoms, the acoustical analysis and the hormonal values were not reported, so there is not a correlation between these topics and VKG findings. As the authors themselves suggested [6], higher androgens could have increased the mass of the vocal fold unevenly and modified their stiffness and tension, leading to increased cycle-to-cycle variability or shaping of lateral peaks. In addition, is important to remember that patients were enrolled in the studies following the Rotterdam criteria [9], that do not require hyperandrogenism to be necessarily present to have a diagnosis of PCOS. Therefore it is reasonable to think that these cohorts of patients with PCOS can be heterogenous regarding hormonal levels, justifying the lack of significant differences compared to control groups, that were expected to be higher.

In PCOS patients, medical prescriptions always need consideration about efficacy, metabolic risk profile, side-effects. From a speculative point of view, assuming that the vocal modifications may depend on the excess of androgens, it is possible that the vocal discomfort may improve following the intake of therapies with an anti-hyperandrogenism effect. Metformin and inositol are commonly used insulin sensitizers that also decrease androgens level [36,37]. While first line therapy for hormonal imbalance is a combined oral contraceptive pill (COCP), less frequent is the use of antiandrogens, which in some cases can be prescribed in combination or as an alternative to combined oral contraceptive pill (COCP) to treat hirsutism and alopecia [38]. Healthcare professionals should be aware of the potential negative psychological impact of clinical hyperandrogenism. As it is suggested to consider the unwanted excess hair growth and/or female pattern hair loss as important, regardless of apparent clinical severity, in our opinion physicians should also pay attention to any complaints of patients for vocal alterations (as tone drops or hoarseness), that could exacerbate low self-esteem and negative body image, resulting in social and/or sexual discomfort.

Besides PCOS, the human voice can be affected also in case of other endocrine pathologies such as thyroid disorders and type 2 diabetes mellitus, but there is uncertain evidence on the topic [39].

### Conclusion

The present analysis suggests that women with PCOS may exhibit more vocal symptoms compared to controls, although the results are not always consistent or easily comparable. The increased prevalence of these symptoms may indicate a change in androgen levels, making voice analysis a feasible valuable tool for follow up. These findings highlight the importance of further investigation into this underestimated aspect of endocrine disorders, as well as the need for attention to the voice health in patients affected by PCOS or undergoing hormonal therapy.

### Statement of Ethics

Ethical approval was not required because this study retrieve and synthesise data from already published studies.

### Conflict of Interests Statement

The authors have no conflicts of interest to declare.

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### Author Contributions

**C.T.:** carrying out, analysing, writing

**A.C.:** carrying out, analysing, writing

**A.G.:** planning, analysing

**M.R.:** planning, analysing

**G.B.:** planning, carrying out, analysing

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**F.P.:** conception of the paper, supervising

**L.M.:** conception of the paper, supervising

**A.P.:** conception of the paper, supervising

**V.D.D.:** conception of the paper, planning, carrying out, analysing

**M.D.V.:** conception of the paper, supervising

### Data Availability Statement

Data can be found in Supplementary Materials. Further enquiries can be directed to the corresponding Author.

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# Figure Legend:

**Figure 1:** Literature search: PRISMA flow-chart

**Figure 2:** Forest plot of comparison: fundamental frequency (F0) in patients with PCOS and healthy control group

**Figure 3:** Forest plot of comparison: noise-to-harmonic ratio (NHR) in patients with PCOS and healthy control group

**Figure 4:** Forest plot of comparison: shimmer in patients with PCOS and healthy control group

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